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Range wide provenance tests of black spruce in Ontario

T.J.B. Boyle

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Petawawa National Forestry Institute

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ABSTRACT

Results are presented for height growth and survival at 10 and 15 years from seed for 76 provenances of black spruce planted at five test sites in Ontario. Provenance-location interactions for height growth were highly significant at both ages, but the interaction for 15-year survival was non-significant. Substantial rank changes occurred between the two ages for height growth but survival ranks were little changed. The best provenance overall was from Nipissing, Ont., but several western Ontario and Quebec sources also performed well.

Based on these results, it is suggested that early selection is not effective in black spruce, that local and regional sources are not necessarily superior to distant sources, but that specific provenances can be selected at age 15 for use in improvement programmes.

RÉSUMÉ

Des données sont présentées sur la croissance en hauteur et la survie aux âges de 10 et 15 ans à partir du semis, pour 76 provenances d'épinette noire à cinq stations d'étude en Ontario. Les interactions provenance-emplacement pour la croissance en hauteur étaient fortement significatives aux deux âges, mais l'interaction pour la survie à 15 ans ne l'était pas. Des différences importantes ont été observées pour le classement des provenances en fonction de la croissance en hauteur entre les deux âges, mais les différences étaient minimes en ce qui concerne le classement en fonction de la survie. Globalement, la meilleure provenance est celle de Nipissing (Ontario), mais plusieurs autres de l'ouest de l'Ontario et du Québec ont également donné de bons résultats.

Il est conclu à partir de ces résultats que la sélection précoce n'est pas efficace dans le cas de l'épinette noire, que les sources locales et régionales ne sont pas nécessairement supérieures aux sources éloignées et que des provenances particulières peuvent être sélectionnées à l'âge de 15 ans pour des programmes d'amélioration.

RANGE-WIDE PROVENANCE TESTS OF BLACK SPRUCE IN ONTARIO

INTRODUCTION

Provenance tests can provide useful information on a number of important problems for the tree breeder. These include the investigation of patterns of variation resulting from genetic forces such as natural selection, migration, and random drift, the preliminary delineation of seed and breeding zones and, possibly, the identification of genetically superior populations (Lines 1967). Black spruce (Picea mariana (Mill.) B.S.P.) has a transcontinental range (Hosie 1979) and is a major commercial species throughout eastern Canada. Provenance testing is therefore a useful first step in an effective genetic improvement programme.

A number of early investigations of provenance variation in black spruce (eg. Morgenstern 1969a, b) indicated that throughout most of its range, variation in juvenile growth characters is predominantly clinal. An exception to this conclusion was reported for Newfoundland and Labrador by Kahlil (1973, 1975), who found patterns of variation which he considered to be ecotypic. Possible reasons for the anomalous situation in Newfoundland include a more complex pattern of climatic gradients than in continental Canada (Kahlil 1981) and the survival of glacial refugia, in which random drift and natural selection resulted in genetic differentiation and from which local migration subsequently took place (Yeh pers. comm.).

In 1967, Dr. E.K. Morgenstern, at the Petawawa National Forestry Institute (PNFI) of the Canadian Forestry Service, initiated the sampling of populations across the natural range of black spruce in cooperation with several agencies in the United States and Canada. Over the next three years seed was collected from 202 populations from Newfoundland to Alaska (Selkirk 1974). Samples of these collections were distributed to cooperating agencies, resulting in the establishment of 33 provenance tests. Results from many of these tests, at various ages, have already been published (Pollard and Logan 1974, 1976, Morgenstern 1978, Segaran 1978, Fowler and Park 1982, Kahlil 1984, Nienstaedt 1984) and largely confirm the conclusions of earlier investigations (eg. Morgenstern 1969a, b). Despite the largely clinal variation, sources from close to the planting site are not necessarily the best in terms of growth and survival (Fowler and Park 1982). Nienstaedt (1984) showed that early selection of black spruce was not effective at the age of three years because correlations with subsequent field performance were not high. Similarly, Corriveau (1982) found that correlations between juvenile growth and 10-year height were not sufficiently large to make early selection effective. These results emphasize the need for a comprehensive series of provenance trials and for continued assessment of the tests.

Five field tests were established in Ontario using sources from the range-wide collection. This information report presents results of 6- and 11-year field measurements (10 and 15 years from seed).

MATERIALS AND METHODS

Seventy six sources, distributed from Newfoundland to the Yukon Territory (Maps 1 and 2), are represented in at least one of the five tests in Ontario (see Appendix I). The test sites (Map 2) are located at:

1. Dryden (Lat. 49°55'N, Long. 92°31'W), where 64 provenances were established in 16 tree plots in a square (8 x 8) lattice design, with three replications;

2. Thunder Bay (Lat. 48°57'N, Long. 89°59'W), where 56 provenances were established in 25 tree plots in a rectangular (7 x 8) lattice design with three replications;

3. Geraldton (Lat. 49°45'N, Log. 86°10'W), where 56 provenances were established in 25 tree plots in a rectangular (7 x 8) lattice design with three replications;

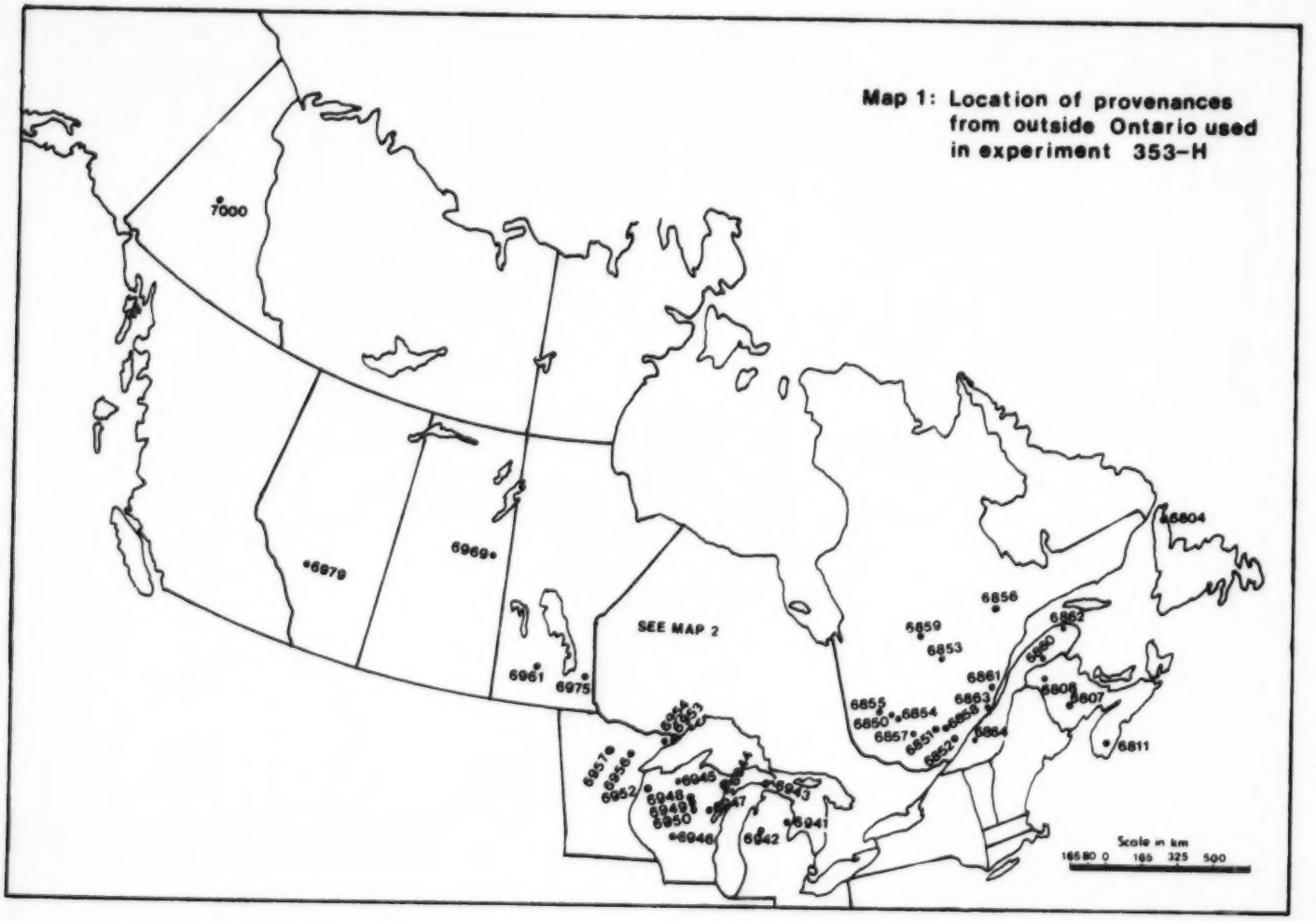
4. Chapleau (Lat. 47°57'N, Long. 83°27'W), where 64 provenances were established in 16 tree plots in a square (8 x 8) lattice design with three replications; and

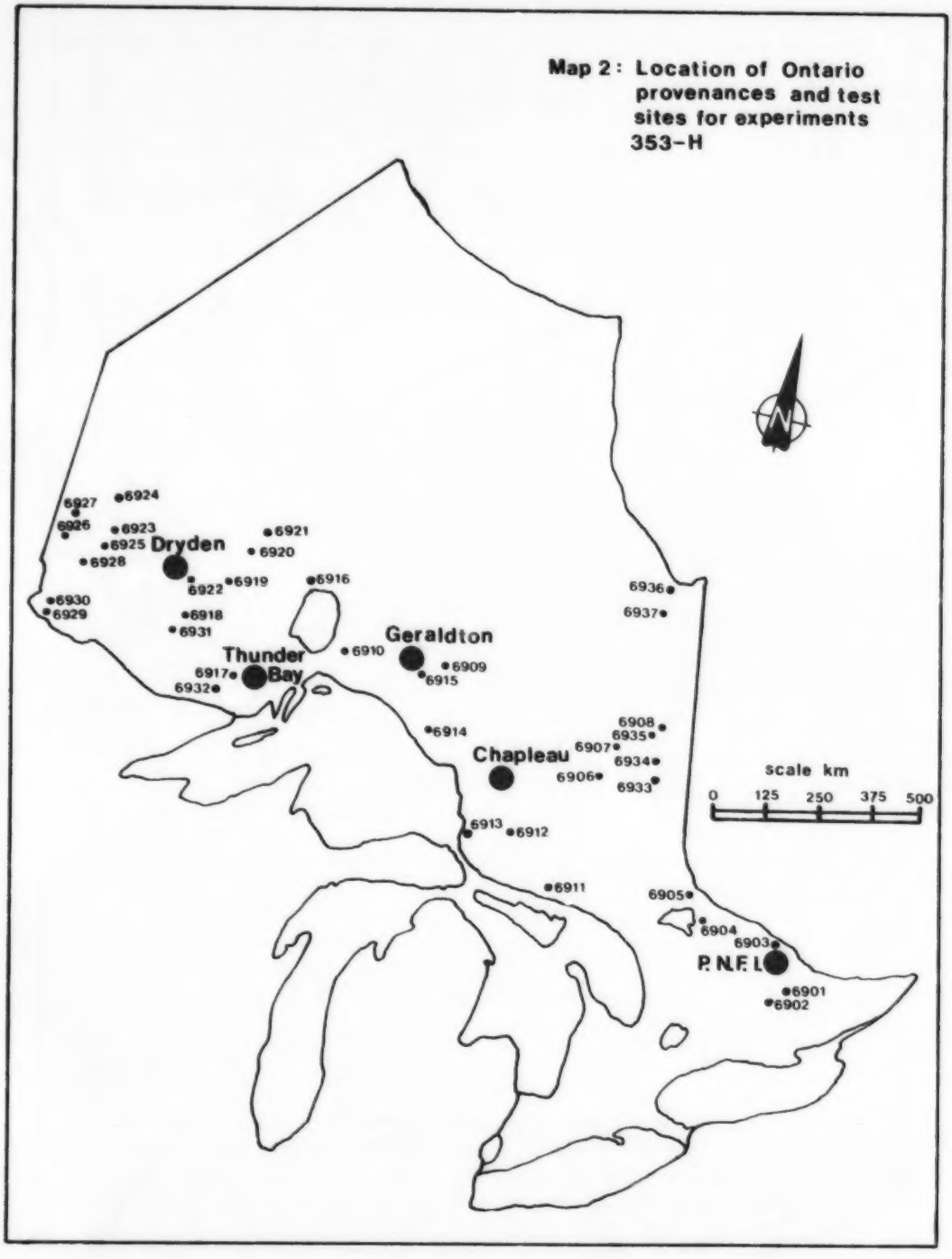
5. Petawawa (PNFI) (Lat. 45°59'N, Long. 77°24'W), where 56 provenances were established in 16 tree plots in a rectangular (7 x 8) lattice design with three replications.

All five tests were planted in 1974, using 2 + 2 stock. Further details of experiment location, site preparation, and establishment are given in Morgenstern and Kokocinski (1976). In 1979 and 1984, after six and 11 growing seasons in the field (10 and 15 years from seed), heights and survival were recorded at every site.

For each site, at both ages, analyses of variance were carried out for both characters (height and survival) based on plot means, following the model for square or rectangular lattice designs given by Cochrane and Cox (1957). In addition, by comparing the error mean squares for the appropriate lattice design and for a randomized complete block design, the statistical efficiency of the experimental design was calculated. Percentage survival figures were normalized by the arcsin transformation (Sokal and Rohlf 1969) before analysis. F values were calculated for the provenance means adjusted by row and, in the case of square lattices, column effects according to the method of Cochrane and Cox (1957). Groups of provenance means that were not significantly different at the 5% level were identified by the cluster analysis method of Scott and Knott (1974), using a FORTRAN 77 programme adapted from the one developed by Gates and Bilbro (1978).

The Scott-Knott cluster analysis means separation test has the advantage over some other means separation tests, for example Duncan's multiple range test, in that each provenance can belong to only a single cluster, making identification of groups of provenances much simpler. But the test procedure has been criticized precisely for this reason, because means are rigidly separated into groups based on a comparison-wise rather than an experiment-wise Type I error rate (Willavize et al. 1980). However, for experiments in which pairwise multiple comparisons may be valid, such as


Map 1: Location of provenances from outside Ontario used in experiment 353-H
7000
6879
6969
6961
6975
SEE MAP 2
6804
6856
6859
6862
6853
6860
6861
6858
6855
6854
6863
6850
6857
6851
6852
6864
6811
6808
6807
6857
6856
6852
6945
6948
6949
6950
6947
6946
6942
6941
Scale in km
165 80 0 165 325 500


Map 2: Location of Ontario provenances and test sites for experiments 353-H
N
6927
6924
6926
6923
6925
Dryden
6921
6928
6920
6922
6919
6916
6930
6929
6918
6931
6936
6937
Geraldton
Thunder Bay
6910
6917
6909
6915
6932
6914
6908
6935
6907
Chapleau
6934
6906
6933
scale km
0 125 250 375 500
6913
6912
6911
6905
6904
6903
P.N.F.L.
6901
6902

provenance trials, cluster analysis methods such as the Scott-Knott procedure are satisfactory (Willavize et al. 1980).

The average performance of each provenance over all sites at which it was planted was computed to enable comparisons among all provenances. In order to give equal weighting to every site, the distribution of provenance means at each site was standardized by subtracting the overall site mean and dividing by the provenance standard deviation. This produced, within each site, a distribution of provenance means having zero mean and unit standard deviation.

Correlation coefficients among 15-year heights at each site, standardized average height and survival at both ages over all sites, heights at ages two and three (Morgenstern 1978), and some ecological and geographic variables used for the same material by Morgenstern (1978) were calculated, together with Spearman rank correlations among heights and survival.

To investigate the levels of provenance-location interaction, an analysis of variance was carried out on the data from all five tests. Due to the different experimental designs, the analysis assumed a randomized complete block design according to the following model:

$$y_{ijk} = \mu + l_i + r_{(ij)} + p_k + (lp)_{ik} + e_{ijk}$$

where

y_{ijk} = response of kth provenance in jth replication at ith site;

μ = overall experimental mean;

l_i = effect of ith site;

$r_{(ij)}$ = effect of jth replication in ith site;

p_k = effect of kth provenance;

$(lp)_{ik}$ = interaction between kth provenance and ith site;

e_{ijk} = random error term.

In addition to having a high average yield across sites, it is advantageous, particularly at an early stage in a tree improvement programme, for a provenance to have a high level of phenotypic stability (Finlay and Wilkinson 1963). Two methods of measuring stability were used, namely Wricke's ecovalence (Wricke 1962) and Tai's stability parameters α and λ (Tai 1971).

Wricke's ecovalence is the contribution of each provenance to the provenance × location sum of squares and is defined as:

$$W_i = \sum_j \left(x_{ij} - \frac{x_{i.}}{q} - \frac{x_{.j}}{p} + \frac{x_{..}}{pq} \right)^2 \text{ where}$$

V_i = ecovalence of the ith provenance

x_{ij} = response of the ith provenance in the jth location

$x_{i.}$ = total response of the ith provenance over all locations

$x_{.j}$ = total response of all provenances at the jth location

$x_{..}$ = overall total

p = number of provenances

q = number of locations

Tai's alpha is similar to the regression coefficient for the regression of provenance response on the environmental index and, therefore, bears a close relationship to parameters produced by other regression techniques such as those of Eberhart and Russell (1966) and Finlay and Wilkinson (1963). Lambda is a measure of the deviation of provenance responses from the linear regression line. Alpha and lambda are respectively defined as:

$$\alpha_i = \frac{s_1.(gl)_i}{(MSL-MSR)/mp} \quad \text{and} \quad \lambda_i = \frac{s^2(gl)_i - \alpha_i s_1.(gl)_i}{(m-1)\ MSE/mp}$$

where:

s_1 = variance of location effects

$(gl)_i$ = interaction effect of the ith provenance over all locations

$s^2(gl)_i$ = variance of interaction effect of ith provenance

MSL = mean square due to locations

MSR = mean square due to replications

MSE = mean square due to error

mp = product of the number of provenances and the number of replications per location

An alpha value of -1 implies that the regression line is flat (ie. having zero slope), whilst an alpha value of zero represents a regression line having a coefficient of one. A "perfectly stable" variety has an alpha value of -1 and a lambda value of 0.

Sundaes (1984) recently discussed the interpretation of these various stability parameters and the relationship among them. He points out that in any discussion of stability parameters, it should be recognized that the estimates obtained apply only to the environments sampled, and also only in relation to the array of provenances sampled.

RESULTS AND DISCUSSION

1. Provenance variation in height growth and survival

Results of the analyses of variance, heights/survival of the ten top-ranked provenances, and Scott-Knott clusters for each test site are given in Tables 1 to 4 for the two characters at both ages. Complete results for all provenances, together with the results of the Scott-Knott cluster analysis and standardized means, are given in Appendices II to V. The experimental mean value for the measured character and the statistical design efficiency for the lattice experimental design, relative to a randomized complete block design, are also given in Tables 1 to 4. Unfortunately, in transferring data from an electronic data collection device to floppy disc, 1984 information for 19 plots at site 1 was lost. Since many of these plots shared the same row or column in the lattice design, and one complete column was lost from replication 1, the lattice square missing plot estimation procedure of Cochrane and Cox (1957) could not produce convergence of the missing plot estimates. The 1984 information for site 1 was, therefore, analyzed as a randomized complete block design, for which the missing plot estimation procedure did converge.

At all test sites, environmental variation accounted for a major proportion of the overall variation. At sites 1 to 4, the variability among replications was the dominant source of variation. For height growth, only at site 5 was the replication mean square not the largest, but at this site the residual error was proportionately much larger than elsewhere. On the other hand, in terms of survival, variation among replications at site 5 was substantial.

At test sites 1 (Dryden), 4 (Chapleau), and 5 (PNFI), differences among provenances were highly significant (1% level) for both height and survival at both measurement ages. At test site 2 (Thunder Bay), differences in height among provenances were not significant in either 1979 or 1984. Differences in survival were significant at the 5% level in 1979 and, by 1984, these differences had increased to become significant a the 1% level. At test site 3 (Geraldton), significant differences among provenances were detected only for height in 1979 (5% level). By 1984 the differences were no longer significant. The experimental efficiency of the square lattice designs (sites 1 and 4) over a randomized complete block design averaged 168%, whilst the efficiency of the rectangular lattices only averaged 108%. Therefore, the efficiency of square lattice designs to account for environmental variation on such sites is very much greater than the randomized complete block design, but the rectangular lattice offers little improvement.

A large environmental contribution to the total observed variation, in the form of among replication differences at sites 1 to 4 and within replication differences at site 5, can be explained by the history and siting of these plantations. Site 1, Dryden, is located on a clay site, which affected early establishment. Thunder Bay (site 2) has suffered extensively from grass competition in the early stages and subsequently from hardwood competition. Establishment at Geraldton (site 3) was uniformly good, but Armillaria mellea (Vahl ex Fr.) Kummer has recently affected some parts of the experiment. At Chapleau (site 4), the experiment is planted on a relatively

Table 1. Analyses of variance for 1979 (10 year) height (cm) at each test and rankings of top 10 provenances

Site	1			2			3			4			5		
Source	DF	MS	F	DF	MS	F	DF	MS	F	DF	MS	F	DF	MS	F
Reps	2	2916.6		2	775.0		2	1458.7		2	273.6		2	81.3	
Provs	63	378.1	3.03**	54	134.2	1.36NS	55	381.4	1.64*	62	254.3	2.18**	49	659.0	2.30**
Rows	21	218.6		21	93.7		21	630.0		21	221.9		21	225.6	
Cols	21	276.0								21	153.2				
Error	84	100.0		88	103.1		89	230.3		83	95.3		83	359.9	
Rank															
1	6910	110.52		6851	108.89		6930	144.01		6954	101.17		6919	135.78	
2	6911	107.27		6918	103.89		6956	123.33		6925	98.35		6943	129.63	
3	6954	106.55		6911	98.32		6933	123.31		6943	97.87		6931	127.90	
4	6932	103.89		6956	96.84		6923	122.04		6952	94.14		6923	123.38	
5	6914	103.85		6924	96.62		6857	120.93		6906	93.92		6901	120.52	
6	6924	102.43		6923	96.07		6935	120.34		6851	93.85		6912	119.47	
7	6946	101.71		6953	95.04		6932	118.46		6931	92.12		6909	117.38	
8	6920	101.31		6906	94.24		6913	118.17		6850	91.79		6913	115.52	
9	6905	101.25		6947	93.96		6949	116.86		6932	91.05		6857	115.21	
10	6918	99.81		6927	93.59		6912	116.83		6864	90.94		6861	113.44	
Expt. X	89.24			87.87			107.44			81.08			99.63		
Design Efficiency	187%			100%			118%			171%			105%		

Notes: Significance levels * 5% ** 1%
Scott-Knott clusters are separated by solid lines
Design efficiency is the statistical efficiency of the lattice experimental design relative to a randomized complete block design

Table 2. Analyses of variance for 1979 (10 year) survival (arcsin) at each test site and rankings (%) of top 10 provenances

Site	1			2			3			4			5		
Source	DF	MS	F	DF	MS	F	DF	MS	F	DF	MS	F	DF	MS	F
Reps	2	0.137		2	0.031		2	0.046		2	0.282		2	2.435	
Provs	63	0.095	2.43**	55	0.034	1.73*	55	0.035	1.21NS	63	0.151	3.16**	55	0.288	3.04**
Rows	21	0.059		21	0.015		21	0.040		21	0.093		21	0.057	
Cols	21	0.055								21	0.048				
Error	84	0.035		89	0.023		89	0.028		84	0.043		89	0.117	

Rank															
1	6804	95.8		6855	77.3		6857	90.7		6853	95.8		6902	100.0	
2	6851	93.7		6901	70.7		6936	84.0		6908	95.8		6854	100.0	
3	6918	91.7		6912	69.3		6914	84.0		6808	93.7		6979	97.9	
4	6902	91.7		6919	69.3		6954	84.0		6852	93.7		6858	97.9	
5	6910	89.6		6922	69.3		6923	82.7		6930	91.7		6903	97.9	
6	6928	89.6		6929	69.3		6925	82.7		6969	91.7		6904	97.9	
7	6932	89.6		6916	68.0		6935	82.7		6961	91.7		6863	95.8	
8	6906	89.6		6903	68.0		6919	82.7		6954	89.6		6862	95.8	
9	6936	89.6		6936	68.0		6932	81.3		6919	87.5		6852	95.8	
10	6909	89.6		6852	68.0		6956	81.3		6933	87.5		6908	95.8	
Expt. X	74.7			57.0			71.2			71.1			73.0		
Design Efficiency	161%			104%			102%			165%			112%		

Notes: Significance levels * 5% ** 1%
Scott-Knott clusters are separated by solid lines
Design efficiency is the statistical efficiency of the lattice experimental design relative to a randomized complete block design

Table 3. Analyses of variance for 1984 (15 year) height (cm) at each test and rankings of top 10 provenances

Site	1			2			3			4			5		
Source	DF	MS	F	DF	MS	F	DF	MS	F	DF	MS	F	DF	MS	F
Reps	2	18160.0		2	7769.8		2	2847.0		2	5363.3		2	680.5	
Provs	45	3174.7	3.03**	54	695.8	1.23NS	55	1173.3	1.44NS	62	1634.7	3.52**	48	6282.1	2.97**
Rows				21	828.4		21	1259.5		21	605.4		21	1374.9	
Cols										21	416.4				
Error	65	1047.1		88	470.1		83	738.6		82	430.1		82	2494.3	
Rank															
1	6911	278.82		6851	238.76		6930	273.34		6850	222.69		6919	384.33	
2	6920	270.74		6918	233.97		6905	257.78		6906	220.11		6943	337.96	
3	6915	270.50		6923	231.79		6957	250.80		6918	216.53		6931	329.40	
4	6954	267.49		6911	221.83		6913	249.50		6902	216.28		6857	322.99	
5	6910	263.42		6905	217.96		6956	247.99		6851	216.15		6901	322.46	
6	6925	259.04		6954	217.28		6933	245.85		6925	216.00		6909	316.10	
7	6933	252.83		6953	216.38		6948	245.55		6924	215.70		6861	314.55	
8	6932	251.03		6934	212.75		6941	244.34		6855	213.01		6923	314.16	
9	6914	250.64		6920	211.88		6953	242.76		6920	211.56		6913	313.49	
10	6917	248.34		6922	211.48		6915	240.64		6931	211.41		6911	310.72	
Expt. X	199.90			198.00			223.57			187.12			270.28		
Design Efficiency	156%			105%			105%			153%			106%		

Notes: Significance levels * 5% ** 1%
Scott-Knott clusters separated by solid lines
Design efficiency is the statistical efficiency of the lattice experimental design relative to a randomized complete block design
Due to loss of data, site 1 had to be analysed as a randomized complete block design

Table 4. Analyses of variance for 1984 (15 year) survival (arcsin) at each test site and rankings (%) of top 10 provenances

Site	1			2			3			4			5		
Source	DF	MS	F	DF	MS	F	DF	MS	F	DF	MS	F	DF	MS	F
Reps	2	0.191		2	0.167		2	0.094		2	0.477		2	2.396	
Provs	44	0.125	1.62**	55	0.038	1.76**	55	0.036	1.27NS	63	0.155	3.30**	55	0.227	3.16**
Rows				21	0.018		21	0.055		21	0.110		21	0.049	
Cols										21	0.042				
Error	65	0.007		89	0.028		89	0.026		84	0.044		89	0.121	

Rank										
1	6804	93.7	6855	72.0	6857	76.0	6908	95.8	6902	100.0
2	6851	89.6	6929	69.3	6954	72.0	6930	91.7	6854	100.0
3	6936	89.6	6908	66.7	6930	72.0	6852	91.7	6969	97.9
4	6918	87.5	6922	65.3	6923	69.3	6969	89.6	6858	97.9
5	6902	87.5	6935	64.0	6952	62.7	6808	89.6	6904	97.9
6	6910	85.4	6936	62.7	6913	62.7	6804	87.5	6852	95.8
7	6906	85.4	6912	61.3	6914	61.3	6853	85.4	6908	95.8
8	6912	85.4	6954	61.3	6851	61.3	6850	85.4	6979	95.8
9	6908	85.4	6919	58.7	6932	60.0	6859	83.3	6903	95.8
10	6924	83.3	6903	58.7	6945	60.0	6851	83.3	6853	93.7
Expt. X	67.6		49.2		51.9		60.9		72.8	
Design Efficiency			104%		110%		171%		120%	

Notes: Significance levels * 5% * 1%
Scott-Knott clusters separated by solid lines
Design efficiency is the statistical efficiency of the lattice experimental design relative to a randomized complete block design
Due to loss of data, site 1 had to be analysed as a randomized complete block design

infertile site in an area that is colder than would be expected, considering the latitude. In all these cases, the effects of competition, disease, and environmental differences are much greater in some parts of the plantation than in others, thus contributing to differences among replicates. Finally, site 5 (PNFI) is planted on a wet site which slopes down into a frost pocket. Running across the slope are a series of hummocks and hollows. The replicates also run across the slope, resulting in relative uniformity among replicates but considerable heterogeneity within them.

2. Provenance-location interaction

The results of the analyses of variance over all locations for the two variables and the two measurement dates are given in Table 5. The F values are only approximate, since Bartlett's test (Sokal and Rohlf 1969) indicated significant heterogeneity among error variances. The χ^2 values for 1984 height and survival were 79.92 and 37.82 (both significant at the 1% level) respectively. However, a log transformation of the height data produced no improvement in the error variance homogeneity (χ^2 = 79.23), so the untransformed data were used. In all cases, variation among sites and among replications within sites was highly significant. For height growth at both ages, variation among provenances and provenance × location interaction were also highly significant. For survival, however, variation among provenances was nonsignificant at both ages, whilst the interaction was significant at the 5% level in 1979, but by 1984 was no longer significant. The highly significant provenance × location interaction terms for height (Table 5) means that broad recommendations of superior populations for use across the province cannot generally be justified. It should be noted though that large environmental main effects (Table 5) tend to inflate the interaction term (Fox and Rosielle 1982).

Some substantial rank changes are still taking place, at least for height. Rank correlations between juvenile and older heights tended to be low (Table 6), with the exception of the correlation with 15-year height at site 5. Because the juvenile heights originated from a nursery trial at PNFI, a strong rank correlation with heights at site 5 (PNFI) is not surprising. In most cases, the correlation with average height was larger than for heights at individual sites. The rank correlation coefficient between average survival at ages 10 and 15 was 0.933.

Despite the highly significant interaction terms for height growth and some major rank changes within individual sites, some consistently fast growing provenances can be identified by comparing standardized mean heights over all sites. The top 15 provenances in terms of standardized height growth at age 15, averaged over all sites (Appendix IV), are:

6905	Nipissing, Ont.
6850	Lebel sur Quevillon, Que.
6923	Perrault Falls, Ont.
6918	Ignace, Ont.
6911	Massey, Ont.
6919	Savant Lake, Ont.
6954	Isabella Lake Co., Minn.
6855	Matagami, Que.

Table 5. Analyses of variance over all locations

	1979 Height				1979 Survival		
Source	DF	MS	F	Source	DF	MS	F
Locations	4	136609.9	40.60***	Locations	4	0.422	26.38***
Reps within locations	10	14115.6	16.37***	Reps within locations	10	0.055	4.07***
Provenance	33	6724.5	2.00***	Provenances	33	0.014	0.88
Loc × prov	132	3364.7	3.90***	Loc × prov	132	0.016	1.22*
Error	6695	862.1		Error	5290	0.013	

	1984 Height				1984 Survival		
Source	DF	MS	F	Source	DF	MS	F
Locations	4	1233345.1	90.38***	Locations	4	0.144	5.33***
Reps within locations	10	53685.0	17.49***	Reps within locations	10	0.121	4.92***
Provenances	33	25428.3	1.86**	Provenances	33	0.033	1.22
Loc × prov	132	13645.5	4.44***	Loc × prov	132	0.027	1.10
Error	5819	3070.3		Error	5290	0.025	

Significance levels: * 5% level; ** 1% level; *** 0.1% level

Table 6. Spearman's rank correlation coefficients among heights at ages 2, 3, 10, and 15

y3	0.743***												
y10	0.388***	0.452***											
y10/1	0.161	0.136	0.563***										
y10/2	0.208	0.290*	0.686***	0.324**									
y10/3	0.297*	0.263*	0.632***	0.185	0.154								
y10/4	0.245	0.349**	0.706***	0.209	0.271	0.121							
y10/5	0.388**	0.329*	0.538***	0.136	0.077	0.254	0.298*						
y15	0.315**	0.337**	0.848***	0.563***	0.555***	0.386**	0.667***	0.552***					
y15/1	0.205	0.173	0.520***	0.861***	0.133	0.292*	0.238	0.164	0.622***				
y15/2	0.114	0.145	0.483***	0.279*	0.774***	0.005	0.287*	0.085	0.657***	0.173			
y15/3	0.118	0.073	0.528***	0.177	0.239	0.680***	0.141	0.175	0.593***	0.249	0.150		
y15/4	0.144	0.216	0.627***	0.264*	0.231	0.077	0.810***	0.267	0.769***	0.329*	0.359*	0.199	
y15/5	0.422**	0.380**	0.574***	0.221	0.003	0.300	0.368**	0.881***	0.639***	0.305*	0.000	0.126	0.308*
	y2	y3	y10	y10/1	y10/2	y10/3	y10/4	y10/5	y15	y15/1	y15/2	y15/3	y15/4

y2 : height at age 2
y3 : height at age 3
$y\bar{a}$: average height over all locations at age a; a = 10,15
ya/b: height at location b, age a; b = 1...5

Significance levels: * 5% ** 1% *** 0.1%

6925 Vermillion Bay, Ont.
6924 Red Lake, Ont.
6933 Kenogami Lake, Ont.
6957 Itasca Co., Minn.
6953 Tofte, Cook Co., Minn.
6857 Parc de la Verendrye, Que.
6851 St. Michel des Saints, Que.

Even among these provenances, some significant rank changes occurred between ages 10 and 15. For example, although 10 of the top 15 provenances in 1984 were also in the top 15 in 1979, the sixth ranked provenance (6919) was ranked 33rd in 1979 and the eighth ranked provenance (6855) was 41st in 1979. Similarly, the third ranked provenance in 1979 (6930) fell to 32nd by 1984.

It would be convenient for tree improvement programmes if there were evidence for regional relationships in performance across the five test sites, resulting for example in Quebec provenances being dominant at PNFI and western Ontario provenances at Dryden. This does not generally hold true, however. Although two Quebec provenances appear in the top 10 at PNFI (Table 3) and three at Chapleau, with only one in the top 10 in the three central/western sites, provenance 6851 (St. Michel des Saints) was the top provenance at Thunder Bay. Similarly, western provenances were first and third at PNFI. Local provenances were above average at four sites, placing 27th, 22nd, 10th, second, and 30th at sites 1 to 5 respectively. Overall, although local and regional provenances tend to perform well, there appears to be a number of provenances, particularly from western Ontario, which exhibit high stability, performing well over a range of sites. There does not, however, seem to be a predictable pattern in the location of widely adaptive provenances. For example, 6918 (Ignace, Ont.) ranked fifth overall, including second at Thunder Bay and third at Chapleau, being the nearest neighbour to 6922 (Sioux Lookout, Ont.), ranked 42nd overall but 22nd at Dryden and 10th at Thunder Bay.

In northern New Brunswick it was found that, generally, superior provenances tended to originate from a few degrees of latitude further south of the test site (Fowler and Park 1982). The same pattern cannot be distinguished in Ontario. Although, at 15 years of age, eight of the 10 tallest provenances at Dryden and all of the top 10 at Geraldton originated from south of the test site, this is largely a reflection of provenance sampling. Only 17 of the 64 provenances at Dryden and 12 out of 56 at Geraldton were more northerly than the test site, and several of those were from extremely northerly latitudes. At PNFI, only two of the top 10 were more southerly provenances, again due to the fact that only nine out of 56 provenances represented at the site originated from further south. When all sites are considered, proportionately slightly more of the tallest provenances came from north of the test sites.

When results from different parts of Canada are compared, certain provenances are found to perform well over a great range of environments. Provenance 6905 (Nipissing, Ont.) in particular, ranking first overall in Ontario, was ranked second overall in 9-year results from 10 test sites in the Maritime provinces (Fowler and Park 1982) and also second overall in 9-year heights at three test sites in Newfoundland (Kahlil 1984). Provenance 6911 (Massey, Ont.) was ranked sixth in Ontario, ninth in the Maritimes and seventh in Newfoundland. On the other hand, some southern latitude Lake States

provenances - 6941 and 6944 - which placed first and fifth respectively in the Maritimes, were 21st and 63rd in Ontario. Also, the top source (6929) from a 12 provenance trial in Manitoba (Segaran 1978) was 59th in Ontario.

3. Correlations among variables

Correlation coefficients among the 23 ecological, geographic, and response variables are given in Table 7. Of the 253 correlations, 136 were significant at the 5% level. In general, seedling heights were correlated with ecological variables more strongly than were later height measurements. The strongest correlations for height were with latitude (negative), degree-days >5.5°C (positive), and length of 5.5°C growing season (positive). This was true both for average height over all locations and for heights at individual locations, at both ages. Correlations between latitude and average height were larger than those between latitude and individual site heights in most cases. The strongest correlations for survival were also with degree-days >5.5°C and length of 5.5°C growing season, but were of opposite sign to those for height.

The lack of any significant correlations between height and survival (Table 7) implies that the best provenances in terms of height growth do not necessarily have superior survival rates. In fact, of the tallest 15 provenances, seven have below average 15-year survival and eight above average. However, providing survival is at least satisfactory, it will have little effect on the final yield, lower survival merely increasing the spacing of the surviving trees, delaying crown closure, and increasing mean diameter. Therefore, provenances should only be eliminated on the basis of survival if they are well below average, or if the cause of low survival can be recognized. The only one of the tallest 15 provenances having very low survival in 1984 was 6911, 74th overall (Appendix V). Nine-year survival of this provenance in the Maritimes however was slightly above average (Fowler and Park 1982).

In spite of the significant negative correlation between height growth and latitude found in this study and others (e.g. Morgenstern 1978, Fowler and Park 1982), five of the tallest 15 provenances come from comparatively northerly latitudes in western Ontario and two more come from the extreme northeast corner of Minnesota, adjacent to the Canadian border. However, although the strong correlations of seedling growth with geographic variables, indicative of clinal variation, persist through to age 15, the size of the correlations is considerably smaller. For example, the correlation between latitude and three-year height growth was -0.767, compared with -0.437 for 15-year average height growth. Pollard and Logan (1974) found strong correlations between latitude of origin and the amount of "free growth" in young black spruce seedlings, but little variation in the amount of "predetermined" growth. Since free growth occurs more frequently in young seedlings, with increasing age the effect of predetermined growth will tend to dominate the effects of juvenile, free growth. It is not surprising, therefore, that the correlations between latitude and height decrease with age. When height growth at individual sites is considered, only at the most southerly site (PNFI) was there a stronger correlation with latitude than there was for average height. This is possibly a reflection of photoperiodic response, with southern provenances flushing earlier without the resultant frost damage that would be suffered on more northerly sites.

Table 7. Correlation coefficient matrix among 31 geographic, ecological, and response variables

x2	-0.740												
x3	-0.588	0.673											
x4	-0.633	0.522	0.674										
x5	0.349	-0.488	-0.578	-0.664									
x6	.	-0.262	.	.	0.507								
x7	.	-0.326	.	.	.	0.493							
x8	0.344	-0.313	-0.366	-0.488	.	-0.309	.						
x9	0.294	.	-0.332	-0.498	.	-0.379	.	0.926					
x10	-0.406	0.433	0.388	0.607	-0.733	-0.290	-0.255	.	.				
x11	-0.410	0.507	0.432	0.646	-0.767	-0.332	-0.276	-0.258	.	0.855			
x12	-0.231	0.351	.	0.402	-0.462	.	.	.	.	0.597	0.602		
x13	.	0.308	.	0.268	-0.337	.	.	.	.	0.517	0.450	0.668	
x14	.	.	.	.	.	.	0.300	.	.	.	0.314	0.666	0.287
x15	-0.365	0.353	0.268	0.381	.	.	.	.	.	0.343	0.324	0.732	.
x16	.	.	.	.	.	.	.	.	.	0.308	0.334	0.726	0.265
x17	.	0.377	.	0.378	-0.432	.	-0.332	.	.	0.536	0.472	0.637	0.307
x18	.	0.280	.	0.336	-0.437	.	.	.	.	0.629	0.579	0.897	0.698
x19	.	0.302	.	0.267	-0.360	.	.	.	.	0.569	0.493	0.644	0.903
x20	.	.	.	.	.	.	0.268	.	.	.	.	0.522	0.296
x21	.	.	.	.	.	.	0.278	.	.	.	.	0.680	.
x22	.	.	.	.	.	0.268	0.269	.	.	0.363	0.312	0.696	0.315
x23	.	0.382	0.275	0.456	-0.544	.	-0.315	.	.	0.641	0.580	0.700	0.442

	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13
x15	.												
x16	0.305	.											
x17	.	.	.										
x18	0.566	0.518	0.684	0.635									
x19	.	.	0.299	0.345	0.753								
x20	0.811	.	0.334	.	0.658								
x21	.	0.776	.	.	0.722	.	.						
x22	0.273	.	0.808	0.335	0.849	0.389	0.405	0.316					
x23	0.307	.	0.422	0.909	0.751	0.519	.	.	0.437				

	x14	x15	x16	x17	x18	x19	x20	x21	x22

x1 : Date of last spring frost
x2 : Date of first fall frost
x3 : Length of 5.5 C season
x4 : Degree days >5.5 C
x5 : Latitude
x6 : Longitude
x7 : Elevation
x8 : Average survival, age 10
x9 : Average survival, age 15
x10: Height, age 2
x11: Height, age 3
x12: Average height, age 10
x13: Height, age 10, site 1
x14: Height, age 10, site 2
x15: Height, age 10, site 3
x16: Height, age 10, site 4
x17: Height, age 10, site 5
x18: Average height, age 15
x19: Height, age 15, site 1
x20: Height, age 15, site 2
x21: Height, age 15, site 3
x22: Height, age 15, site 4
x23: Height, age 15, site 5

Note: All coefficients not significant at the 5% level not reported.

4. Provenance stability

Wricke's ecovalence and Tai's stability parameters were calculated for all provenances which were used in more than one location and the results are given in Table 8. For each provenance, the parameters were estimated based on the performance of all provenances represented at the same combination of sites. For example, in the case of provenance 6851, which was used at every location, the various measures of stability were calculated based on the performances of the 34 provenances found at every site. On the other hand, for provenance 6811, which was only used at sites 4 and 5, results were based on the performances at sites 4 and 5 of all 50 provenances represented at both of these locations. Strictly speaking, comparisons can only be made among those provenances that were represented in the same combination of sites.

The rank correlation coefficient between ecovalences and Tai's α was -0.141, which was non-significant, and that between ecovalences and Tai's λ was 0.477, significant at the 0.1% level.

It has already been noted that some provenances, such as 6905 and 6911, appear to be highly stable, being fast growing in a wide range of environments from Ontario to Newfoundland, whereas others perform well on only a few sites. Of the top 15 yielding provenances in Ontario, all but two are more stable than average ($\bar{x}$ = 1354.3), which is not surprising, since to be ranked in the top 15, a provenance would need consistent results over all sites. The two exceptions are 6919 and, surprisingly, given its superior performance throughout eastern Canada, 6911. The former actually has the highest ecovalence of all provenances, implying that it should only be used for site-types on which it has proved itself, namely PNFI, at which it was easily the fastest growing, and the Geraldton site, where it ranked 11th. Provenance 6905, consistently one of the best provenances throughout eastern Canada and the Great Lakes States, is not among the most stable provenances in Ontario although it has a lower than average ecovalence (824.2). The provenances having the lowest ecovalences are mainly from eastern Canada - New Brunswick (6808), Nova Scotia (6811), and Quebec (6859 and 6864). Provenances from the extremes of the range have below average ecovalences (above average stability), reflecting the fact that these sources perform equally poorly on all sites.

Both Wricke's and Tai's methods give similar results. Provenances from Quebec and the extremes of the range demonstrate superior stability, but Maritime provenances have alpha values greater than zero, or below average stability. Provenances 6911 and, especially, 6919 are unstable, but seven more of the top 15 provenances have positive alpha values, although many are close to zero.

Wricke's ecovalence and Tai's lambda both measure the deviation of individual provenance responses from a linear relationship and can be shown mathematically to be closely related (Morgenstern and Teich 1971), as was found in this case with a highly significant rank correlation between the two parameters. This deviation may imply a degree of unpredictability in the response of the provenance (Fowler and Park 1982), or may result from a predictable but non-linear response.

Table 8. Tai's stability parameters and Wricke's Ecovalences calculated for black spruce spruce provenances in Expt. 353h

Variable: 1984 (15-year) height				
Sites	Provenance	Alpha	Lambda	Ecovalence
1 45	6804	-0.15	0.09	1620.6
1 45	6807	0.37	-0.01	277.7
45	6808	0.04	0.00	35.8
45	6811	0.39	-0.01	35.0
45	6850	-0.13	0.00	223.2
12345	6851	-1.13	0.05	6284.8
12345	6852	-0.04	0.54	722.9
45	6853	-0.30	0.00	525.2
1 345	6854	-0.58	0.80	2799.1
2345	6855	-0.10	0.05	586.2
1 345	6857	0.38	1.07	1156.7
12345	6858	-0.02	0.43	509.9
45	6859	-0.20	0.00	45.6
45	6862	0.02	0.00	472.1
1 45	6863	0.11	1.31	596.5
1 45	6864	-0.05	0.79	22.4
12345	6901	0.56	0.98	2700.3
12345	6902	-0.38	0.68	1596.9
123 5	6903	-0.24	0.14	1162.6
23 5	6904	-0.31	0.01	309.6
123	6905	0.11	0.41	824.2
12345	6906	-0.56	0.14	1747.8
12345	6907	-0.57	0.90	2708.1
12345	6908	-0.54	1.37	593.7
12345	6909	0.52	0.59	2029.1
12345	6910	-0.19	0.76	1134.7
12345	6911	0.30	1.33	2041.1
12345	6912	0.65	0.08	2063.5
12345	6913	0.60	0.54	2360.8
12345	6914	0.16	0.77	1055.4
1234	6915	1.75	-0.42	309.0
123	6916	-0.16	0.11	493.7
12345	6917	0.04	0.18	239.0
12345	6918	-0.60	0.16	1963.1
12345	6919	1.22	0.72	7983.8
12345	6920	-0.35	1.60	2627.9
1234	6921	-0.37	0.19	551.9
12345	6922	-0.54	1.38	3117.7
12345	6923	0.15	0.64	889.5
12345	6924	0.06	0.19	280.5
12345	6925	0.05	0.51	675.0
12	6926	1.05	-0.29	43.7
1234	6927	-0.04	0.16	450.7
1234	6928	0.15	0.13	743.9
12 4	6929	0.12	0.67	677.0
12345	6930	-0.22	2.83	3794.4

Table 8 (cont'd)

Variable: 1984 (15-year) height				
Sites	Provenance	Alpha	Lambda	Ecovalence
12345	6931	0.41	1.72	2999.4
12345	6932	0.05	0.60	792.1
12345	6933	-0.07	0.53	707.0
1234	6934	-2.02	8.91	1824.6
234	6935	-0.86	0.21	1844.8
12345	6936	-0.26	0.35	740.2
123	6937	-0.72	2.13	826.8
12345	6941	0.08	0.53	665.4
12345	6942	0.05	1.06	1344.4
12345	6943	0.70	0.47	2887.6
1234	6944	1.24	-0.23	972.4
123	6945	-0.01	0.12	808.7
1234	6946	0.37	1.12	869.4
12345	6947	-0.07	0.26	350.1
12345	6948	0.03	0.57	724.9
1234	6949	1.26	0.88	238.0
1 4	6950	-0.21	-0.01	747.6
1234	6952	-0.70	0.60	388.2
12345	6953	-0.13	0.26	391.2
12345	6954	0.04	0.83	1047.0
1234	6956	0.72	0.80	716.1
1234	6957	0.16	0.67	1164.0
1 345	6961	-0.69	1.08	5287.7
1 45	6969	-0.37	0.41	5274.9
12 4	6975	-0.75	0.01	846.5
1 5	6979	-0.50	-0.03	310.5
1 5	7000	-0.79	-0.06	1014.2

Provenances with an alpha value close to -1 perform relatively better on less productive sites than on more favourable sites (Skróppa 1984). Such provenances should therefore be selected if most planting sites are expected to be less productive than the test sites, or if separate breeding populations are being developed for poor and good sites. In the latter case, provenances with high positive alpha values should be selected for the productive site breeding population since they perform relatively better than expected on good sites. An excellent example is provenance 6919 - easily the tallest provenance on the most productive site, 12th tallest on the second most productive, but only average or below average on the less productive sites, resulting in an alpha value of 1.22.

CONCLUSIONS

At 15 years from seed, substantial rank changes are still occurring among provenances in terms of height growth, but not survival. For this reason, early selection of black spruce provenances for height growth is unlikely to be successful, as found by Nienstaedt (1984) and results from at least 15-year-old provenance tests should be used in selecting populations for further study or for inclusion in improvement programs. The rapidly decreasing correlation between height and latitude with increasing age indicates that the predominantly clinal pattern of variation found for seedling characters and free growth (Morgenstern 1978, Pollard and Logan 1974) does not apply so strongly for subsequent "predetermined" growth.

There is a group of apparently superior sources from western Ontario which perform well across the province, even on more southerly sites, and a secondary group of fast-growing Quebec provenances which are highly stable. The overall best provenance in Ontario, though, is 6905 (Nipissing, Ont.), which has also been found to be an excellent source for Newfoundland (Kahlil 1984) and the Maritimes (Fowler and Park 1982). However, a strong genotype × environment interaction term in the analysis of variance indicates that results from individual sites, rather than overall averages, should be used in determining the best provenances for different regions.

There does not appear to be a predictable pattern of regionality in the results - in western Ontario, for instance, local sources are not necessarily the best, nor is there any obvious relationship among the top sources. Breeding zones are therefore difficult to determine from these results. Neighbouring provenances often exhibit radically different ranks: for example 6905 (first) and 6904 (58th); 6933 (12th) compared with 6934 (52nd). Although this may reflect genuine differences in average breeding value of individuals within these populations, it could also result from different levels of inbreeding and differing population structure.

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APPENDICES

Appendix I. Location of the 76 provenances used in the five Ontario tests and the tests in which they were used

No.	Provenance	Lat. (M)	Long. (M)	Elev. (a)	1	2	3	4	5
6804	Roddickton, Nfld.	50°54'	56°06'	50	x			x	x
6807	Base Gagetown, N.B.	45°35'	66°29'	90	x			x	x
6808	States Lake, Rest. Co., B.	47°55'	67°49'	370				x	x
6811	Southwestern Nova Scotia	44°00'	65°15'	70				x	x
6850	Lebel sur Quevillon, Que.	49°07'	76°57'	310				x	x
6851	St. Michel des Saints, Que.	46°50'	74°25'	520	x	x	x	x	x
6852	Lower Mattawin, Que.	46°55'	73°26'	300	x	x	x	x	x
6853	Lac Pimbina, Que.	46°55'	73°30'	300				x	x
6854	Canton Augier, Abitibi Est, Que.	48°36'	76°41'	440	x		x	x	x
6855	Matagami, Que.	49°37'	77°45'	270		x	x	x	x
6856	Manicouagan, Que.	50°40'	68°46'	430					x
6857	Parc de la Verendrye, Que.	47°05'	76°33'	360	x		x	x	x
6858	Riviere aux Rata, Que.	47°18'	73°06'	305	x	x	x	x	x
6859	Parc Mistassini, Que.	50°27'	73°38'	370				x	x
6860	Causapacal, Que.	48°30'	67°07'	240					x
6861	Mars Ha! Ha!, Que.	48°12'	70°56'	240					x
6862	Murdochville, Que.	48°55'	65°25'	610				x	x
6863	Valcartier II, Que.	46°55'	71°31'	180	x			x	x
6864	Perthuis, Que.	46°56'	72°06'	270	x			x	x
6901	Dungannon Tp., Hastings Co., Ont.	45°10'	77°10'	350	x	x	x	x	x
6902	Cardiff Tp., Haliburton Co., Ont.	44°50'	78°05'	330	x	x	x	x	x
6903	Buchanan Tp., Renfrew Co., Ont.	45°58'	77°25'	160	x	x	x		x
6904	Widdifield Tp., Nipissing Dist., Ont.	46°25'	79°26'	410		x	x		x
6905	Olive Tp., Nipissing Dist., Ont.	46°55'	79°42'	330	x	x	x		
6906	Muskego Tp., near Foleyet, Ont.	48°12'	82°23'	340	x	x	x	x	x
6907	Ogden Tp., W. of Timmins, Ont.	48°32'	81°25'	300	x	x	x	x	x
6908	Stimson Tp., E. of Iroquois Falls, Ont.	48°59'	80°38'	300	x	x	x	x	x
6909	Kohler Tp., W. of Otasawian River, Ont.	49°45'	85°05'	210	x	x	x	x	x
6910	Summers Tp., SE. of Beardmore, Ont.	49°40'	87°50'	300	x	x	x	x	x
6911	Tennyson Tp., 8 miles N. of Massey, Ont.	46°20'	82°50'	240	x	x	x	x	x

Appendix I (cont'd)

No.	Provenance	Lat. (M)	Long. (M)	Elev. (a)	1	2	3	4	5
6912	Whitman Tp., NE. of Searchmont, Ont.	46°46'	83°26'	370	x	x	x	x	x
6913	Fenwick Tp., S. of Goulais River, Ont.	46°43'	84°23'	210	x	x	x	x	x
6914	Hunt Tp., W. of White River, Ont.	48°38'	85°20'	370	x	x	x	x	x
6915	Manitouwadge, Ont.	49°08'	85°47'	310	x	x	x	x	
6916	Armstrong, Ont.	50°18'	89°11'	340	x	x	x		
6917	Joynt Tp., SE. of Upsala, Ont.	49°00'	90°27'	470	x	x	x	x	x
6918	Ignace Tp., S. of Ignace, Ont.	49°25'	91°31'	460	x	x	x	x	x
6919	Boucher Tp., N. of Savant Lake, Ont.	50°19'	90°41'	400	x	x	x	x	x
6920	Minchin Lake, S. of Lake St. Joseph, Ont.	50°44'	90°34'	380	x	x	x	x	x
6921	Pickle Lake, 2 mi. S. of Patricia, Ont.	51°28'	90°11'	400	x	x	x	x	
6922	Sioux Lookout, 20.5 mi. NE. of town, Ont.	50°13'	91°40'	400	x	x	x	x	x
6923	Perrault Falls, 20 mi. S. of Ear Falls, Ont.	50°24'	93°20'	350	x	x	x	x	x
6924	Red Lake, Ont., 10 mi. S. of town.	50°53'	93°44'	350	x	x	x	x	x
6925	Vermilion Bay, Ont., 6.7 mi. S. of town.	49°50'	93°30,	380	x	x	x	x	x
6926	Kenora, Ont., 20 mi. W. of town on Sherwood Lake Rd.	50°03'	94°52'	340	x	x			
6927	Minski, near Pistol Lake, Ont.	50°50'	94°17'	340	x	x	x	x	
6928	Nestor Falls, Ont., 2.5 mi. N. of town.	49°20'	93°55'	340	x	x	x	x	
6929	Devlin, on Hwy. 613, 5 mi. N. of Junction with Hwy. 11	48°44'	93°40'	350	x	x		x	
6930	Rainy Lake, Ont.	48°48'	93°40'	370	x	x	x	x	x
6931	Atikokan, Ont., SW. of town on Hwy. 11.	48°44'	91°40'	380	x	x	x	x	x
6932	Shebandowan, Ont.	48°40'	90°11'	450	x	x	x	x	x
6933	Gross Tp., 12 mi. SW. of Kenogami Lake, Ont.	48°00'	80°08'	300	x	x	x	x	x

Appendix I (cont'd)

No.	Provenance	Lat. (M)	Long. (M)	Elev. (a)	1	2	3	4	5
6934	Sheraton Tp., E. of Nighthawk Lake, Ont.	48°27'	80°47'	290	x	x	x	x	
6935	Potter, Ont.	48°52'	80°52'	270		x	x	x	
6936	Moose Tp. near Moosonee, Ont.	51°16'	80°46'	60	x	x	x	x	x
6937	Winnington Tp., S. of Moosonee, Ont.	51°06'	80°52'	60	x	x	x		
6941	Huron N.F., Oscoda Co., Mich.	44°38'	84°20'	320	x	x	x	x	x
6942	Manistee N.F., Wexford Co., Mich.	44°12'	85°35'	180	x	x	x	x	x
6943	Hiswatha N.F., MacKinac Co., Mich.	46°03'	84°47'	210	x	x	x	x	x
6944	Hiswatha N.F., Delta Co., Mich.	45°59'	86°51'	180	x	x	x	x	
6945	Ottawa N.F., Gogebic Co., Mich.	46°24'	89°42'	470	x	x	x		
6946	Mather, Jackson Co., Wis.	44°13'	90°22'	290	x	x	x	x	
6947	Lakewood, Oconto Co., Wis.	45°17'	88°27'	400	x	x	x	x	x
6948	Forest Co. I, Wis.	45°44'	88°59'	460	x	x	x	x	x
6949	Forest Co. II, Wis.	45°44'	89°03'	460	x	x	x	x	
6950	Forest Co. II, Wis.	46°58'	88°55'	460	x			x	
6952	Hayward, Sawyer Co., Wis.	46°07'	90°56'	460	x	x	x	x	
6953	Tofte, Cook Co., Minn.	47°37'	90°52'	680	x	x	x	x	x
6954	Isabella, Lake Co., Minn.	47°42'	91°18'	400	x	x	x	x	x
6956	Virginia, St. Louis Co., Minn.	47°42'	92°28'	420	x	x	x	x	
6957	Marcell, Itasca Co., Minn.	47°32'	93°43'	470	x	x	x	x	
6961	Riding Mtn., Man.	50°45'	99°58'	680	x		x	x	x
6969	Jan Lake, Sask.	54°52'	102°48'	340	x			x	x
6975	Whiteshell Prov. Park, Man.	50°04'	95°27'	330	x	x		x	
6979	Rocky Mtn. House, Alta.	52°22'	115°15'	1070	x				x
7000	Mayo, Y.T.	63°34'	135°55'	500	x				x

Appendix II. Ten year (1979) height growth (cm) and Scott-Knott clusters for all five test sites

Prov.	Site 1	2	3	4	5	Means Raw	Means Standardized
6804	72.02 C			63.15 A	82.45 C	72.54	-0.3219
6807	74.96 C			73.77 C	106.19 E	84.97	-0.1172
6808				84.33 E	102.35 E	93.34	0.0574
6811				68.68 B	99.09 E	83.89	-0.1567
6850				91.79 G	107.72 E	99.76	0.1835
6851	93.44 G	108.89 G	107.38 F	93.85 G	79.63 C	96.64	0.1866
6852	84.25 E	78.83 A	106.96 F	90.10 G	101.21 E	92.27	-0.0405
6853				88.19 F	87.87 D	88.03	0.0138
6854	96.98 H		114.39 F	79.79 D	100.42 E	97.89	0.0796
6855		88.31 C	101.30 D	85.49 E	104.42 E	94.88	0.0018
6856					98.65 E	98.65	-0.0124
6857	81.15 E		120.93 I	84.74 E	115.21 F	100.51	0.1343
6858	83.95 E	83.81 B	95.75 C	62.19 A	90.41 D	83.22	-0.2345
6859				72.18 B	86.65 C	79.42	-0.1919
6860					98.07 E	98.07	-0.0197
6861					113.44 F	113.44	0.1742
6862				66.15 A	81.80 C	73.98	-0.2971
6863	72.06 C			77.93 C	91.89 D	80.63	-0.1602
6864	80.58 E			90.94 G	103.05 E	91.52	0.0444
6901	81.23 E	81.09 B	102.66 D	81.32 D	120.52 F	93.36	-0.0539
6902	83.86 E	92.28 D	102.47 D	90.23 G	111.25 E	96.02	0.0599
6903	83.59 E	93.49 D	111.60 G		103.46 E	98.04	0.0706
6904		84.54 B	98.53 D		95.31 D	93.13	-0.1428
6905	101.25 I	92.30 D	112.30 G			101.95	0.1743
6906	93.99 G	94.24 D	101.56 D	93.92 G	83.96 C	93.53	0.0548
6907	88.14 F	82.69 B	97.67 C	70.81 B	76.92 A	83.25	-0.2083
6908	80.42 E	81.54 B	94.01 B	84.05 E	88.88 D	85.78	-0.1702
6909	81.26 E	83.66 B	96.96 C	80.41 D	117.38 F	91.93	-0.0800
6910	110.52 J	91.84 D	108.08 F	89.37 F	102.29 E	100.42	0.1571
6911	107.27 J	98.32 E	115.76 H	81.18 D	91.39 D	98.78	0.1715
6912	98.28 J	85.02 B	116.83 H	77.50 C	119.47 F	99.42	0.0977
6913	84.96 F	83.44 B	118.17 H	76.38 C	115.52 F	95.69	0.0307
6914	103.85 I	89.30 C	92.94 B	77.79 C	94.17 D	91.61	-0.0520
6915	98.70 H	85.94 B	111.86 G	69.98 B		91.62	-0.0127
6916	89.30 G	87.87 C	107.53 F			94.90	0.0012
6917	99.09 H	89.93 C	103.55 D	86.21 E	103.08 E	96.37	0.0619
6918	99.81 I	103.89 E	104.71 D	85.30 E	101.64 E	99.07	0.1690
6919	92.38 G	85.83 B	104.89 D	76.17 C	135.78 G	99.01	0.0477
6920	101.31 I	84.53 B	92.01 B	83.19 E	97.65 E	91.74	-0.0671
6921	93.90 G	74.96 A	101.34 D	75.79 C		86.50	-0.1789
6922	97.34 H	89.83 C	110.57 G	78.15 C	86.46 C	92.47	0.0142
6923	90.90 G	96.07 E	122.04 I	87.76 F	123.38 F	104.03	0.2463
6924	102.43 I	96.62 E	103.42 D	84.06 E	110.28 E	99.36	0.1313
6925	93.14 G	87.96 C	110.51 G	98.35 H	97.31 E	97.45	0.1120
6926	94.02 G	76.90 A				85.46	-0.1655
6927	96.75 H	93.59 D	113.64 G	80.43 D		96.10	0.1288
6928	96.74 H	89.55 C	98.93 D	79.16 D		91.10	-0.0248

Appendix II (cont'd)

Prov.	Site 1	2	3	4	5	Means Raw	Means Standardized
6929	94.28 G	88.26 C		81.28 D		87.94	0.0364
6930	83.31 E	88.33 C	144.01 E	88.18 F	95.61 D	99.89	0.2209
6931	77.89 D	88.07 C	105.25 D	92.12 G	127.90 G	98.25	0.0744
6932	103.89 I	86.26 B	118.46 H	91.05 G	97.56 E	99.44	0.1482
6933	94.75 G	80.82 B	123.31 I	84.92 E	104.16 E	97.59	0.0892
6934	81.13 E	89.07 C	96.41 C	76.25 C		85.71	-0.1350
6935		81.52 B	120.34 I	79.76 D		93.87	0.0344
6936	83.78 E	82.33 B	91.51 B	71.11 B	83.87 C	82.52	-0.2435
6937	80.51 E	76.36 A	71.55 A			76.14	-0.5464
6941	90.86 G	89.36 C	116.42 H	74.73 C	104.62 E	95.20	0.0507
6942	74.57 C	91.46 D	89.80 B	81.96 E	103.70 E	88.30	-0.1132
6943	92.11 G	91.45 D	102.21 D	97.87 H	129.63 G	102.65	0.1655
6944	99.05 H	74.02 A	108.10 F	63.06 A		86.06	-0.1943
6945	83.21 E	84.52 B	103.67 D			90.47	-0.1147
6946	101.71 I	89.90 C	108.81 F	76.28 C		94.18	0.0549
6947	87.92 F	93.96 D	115.41 H	81.19 D	102.11 E	96.12	0.0948
6948	86.64 F	81.03 B	115.77 H	90.18 G	89.58 D	92.64	0.0072
6949	78.19 D	84.42 B	116.86 H	72.67 B		88.04	-0.0650
6950	86.45 F			80.75 D		83.60	-0.0288
6952	97.17 H	83.04 B	115.67 H	94.14 G		97.51	0.1302
6953	97.54 H	95.04 D	113.55 G	84.86 E	106.45 E	99.49	0.1554
6954	106.55 H	92.27 D	107.07 F	101.17 H	111.24 E	103.66	0.2213
6956	88.81 F	96.84 E	123.33 I	64.00 A		93.25	0.0935
6957	96.58 H	87.61 C	115.19 H	89.17 F		97.14	0.1367
6961	86.91 F		92.85 B	72.03 B	80.63 C	83.11	-0.2327
6969	80.32 E			70.07 B	84.76 C	78.38	-0.2061
6975	85.71 F	87.62 C		69.25 B		80.86	-0.1215
6979	62.76 B				64.28 B	63.52	-0.4580
7000	45.24 A				65.66 B	55.45	-0.6048

Appendix III. Ten year (1979) survival (%) and Scott-Knott clusters for all five test sites

Prov.	Site 1	2	3	4	5	Means Raw	Means Standardized
6804	95.8 H			87.5 H	79.2 E	85.40	0.0036
6807	60.4 D			70.8 F	77.1 E	69.43	-0.0010
6808				93.7 H	91.7 F	92.70	0.0055
6811				68.7 E	89.6 F	79.15	0.0003
6850				87.5 H	93.7 F	90.60	0.0042
6851	93.7 H	62.7 E	72.0 D	85.4 G	52.1 D	73.18	0.0010
6852	79.2 F	68.0 G	76.0 E	93.7 H	95.8 F	82.54	0.0039
6853				95.8 H	93.7 F	94.75	0.0062
6854	83.3 F		74.7 E	75.0 G	100.0 F	83.25	0.0026
6855		77.3 F	61.3 B	85.4 H	47.9 C	67.98	0.0016
6856					83.3 E	83.30	0.0014
6857	85.4 F		90.7 F	81.2 G	66.7 D	81.00	0.0028
6858	81.2 F	52.0 D	69.3 D	54.2 D	97.9 F	70.92	-0.0004
6859				83.3 G	91.7 F	87.50	0.0029
6860					72.9 E	72.90	-0.0007
6861					93.7 F	93.70	0.0027
6862				83.3 G	95.8 F	89.55	0.0037
6863	58.3 C			72.9 F	95.8 F	75.67	0.0002
6864	66.7 D			83.3 H	95.8 F	81.93	0.0021
6901	64.6 D	70.7 G	64.0 C	77.1 F	89.6 F	73.20	0.0008
6902	91.7 H	58.7 E	57.3 B	72.9 F	100.0 F	76.12	0.0010
6903	81.2 F	68.0 G	62.7 C		97.9 F	77.45	0.0018
6904		46.7 C	69.3 D		97.9 F	71.30	0.0000
6905	60.4 D	46.7 C	50.7 A			52.60	-0.0046
6906	89.6 G	56.0 D	73.3 E	81.2 G	56.2 D	71.26	0.0007
6907	81.2 F	57.3 E	69.3 D	50.0 C	39.6 C	59.48	-0.0023
6908	89.6 A	61.3 E	76.0 E	95.7 H	95.8 F	83.28	0.0042
6909	89.6 H	61.3 E	77.3 E	75.0 F	77.1 E	76.06	0.0019
6910	89.6 H	54.7 D	68.0 D	83.3 G	45.8 C	68.28	0.0003
6911	60.4 E	28.0 A	68.0 D	58.3 D	18.7 A	46.68	-0.0061
6912	87.5 G	69.3 G	76.0 E	75.0 F	87.5 F	79.06	0.0021
6913	79.2 F	64.0 E	78.7 G	54.2 D	45.8 C	64.38	-0.0004
6914	89.6 H	44.0 C	84.0 G	87.5 H	47.9 C	70.60	0.0008
6915	85.4 G	52.0 D	73.3 E	60.4 E		67.78	-0.0003
6916	79.2 F	68.0 G	48.0 A			65.07	-0.0004
6917	83.3 F	60.0 E	76.0 E	72.9 F	81.2 E	74.68	0.0010
6918	91.7 H	64.0 E	72.0 E	68.7 E	87.5 F	76.78	0.0017
6919	64.6 D	69.3 G	82.7 G	87.5 H	31.2 B	67.06	0.0011
6920	87.5 G	49.3 D	72.0 E	66.7 E	91.7 F	73.44	0.0003
6921	87.5 G	61.3 E	48.0 A	54.2 D		62.75	-0.0017
6922	79.2 F	69.3 G	69.3 D	54.2 D	31.2 B	60.64	-0.0014
6923	70.8 E	58.7 E	82.7 G	79.2 G	60.4 D	70.36	0.0005
6924	89.6 H	44.0 C	70.7 E	56.2 D	89.6 F	70.02	-0.0008
6925	52.1 B	53.3 D	82.7 G	70.8 F	39.6 C	59.70	-0.0016
6926	68.7 E	62.7 E				65.70	0.0004
6927	66.7 D	58.7 E	68.0 D	39.6 C		58.25	-0.0030
6928	89.6 G	56.0 D	70.7 E	85.4 G		75.43	0.0016

Appendix III (cont'd)

Prov.	Site 1	2	3	4	5	Means Raw	Means Standardized
6929	79.2 F	69.3 G		77.1 F		75.20	0.0023
6930	47.9 B	44.0 C	76.0 E	91.7 H	58.3 D	63.58	-0.0009
6931	70.8 E	56.0 D	70.7 D	68.7 E	45.8 C	62.40	-0.0016
6932	89.6 H	60.0 E	81.3 G	83.3 H	58.3 D	74.50	0.0020
6933	79.2 F	53.3 D	54.7 B	87.5 H	87.5 F	72.44	0.0002
6934	77.1 E	52.0 D	62.7 C	41.7 C		58.38	-0.0034
6935		61.3 E	82.7 G	37.5 C		60.50	-0.0014
6936	89.6 G	68.0 G	84.0 G	77.1 F	77.1 E	79.16	0.0026
6937	81.2 F	60.0 E	65.3 C			68.83	-0.0001
6941	83.3 G	52.0 D	77.3 E	50.0 D	64.6 D	65.44	-0.0009
6942	72.9 E	58.7 E	58.7 B	70.8 F	64.6 D	65.14	-0.0012
6943	72.9 E	53.3 D	72.0 E	72.9 F	58.3 D	65.88	-0.0011
6944	37.5 A	37.3 B	69.3 D	29.2 B		43.33	-0.0075
6945	47.9 B	40.0 B	74.7 E			54.20	-0.0038
6946	37.5 A	44.0 C	57.3 B	43.7 C		45.63	-0.0066
6947	47.9 B	62.7 E	72.0 D	62.5 E	54.2 D	59.86	-0.0021
6948	72.9 E	46.7 C	60.0 B	75.0 F	60.4 D	63.00	-0.0022
6949	56.2 C	49.3 D	74.7 E	70.8 F		62.75	-0.0015
6950	64.6 D			77.1 F		70.85	-0.0007
6952	70.8 E	61.3 E	74.7 E	77.1 G		70.97	0.0008
6953	72.9 E	56.0 D	69.3 D	81.2 G	77.1 E	71.30	0.0002
6954	70.8 E	64.0 E	84.0 G	89.6 H	70.8 E	75.84	0.0021
6956	60.4 D	60.0 E	81.3 G	18.7 A		55.10	-0.0034
6957	75.0 F	64.0 E	76.0 E	39.6 C		63.65	-0.0013
6961	77.1 F		76.0 G	91.7 H	58.3 D	75.78	0.0025
6969	87.5 G			91.7 H	95.8 F	91.67	0.0046
6975	58.3 D	48.0 D		41.7 C		49.33	-0.0054
6979	66.7 E				97.9 F	82.30	0.0015
7000	77.1 E				35.4 B	56.25	-0.0028

Appendix IV. Fifteen year (1984) height growth (cm) and Scott-Knott clusters for all five test sites

Prov.	Site 1	2	3	4	5	Means	
						Raw	Standard-ized
6804	164.67 C			124.27 A	199.17 C	162.70	-1.1659
6807	210.44 E			166.01 C	282.92 F	219.79	-0.1988
6808				184.57 E	273.74 F	229.15	-0.0098
6811				148.33 B	267.46 E	207.90	-0.4976
6850				222.69 H	296.95 H	259.82	0.6081
6851	221.81 F	238.76 G	226.75 E	216.15 H	218.49 D	224.39	0.3342
6852	228.25 F	175.43 A	228.21 E	204.39 G	273.63 F	221.98	-0.0337
6853				197.94 F	257.60 E	227.77	0.0537
6854	234.03 G		239.20 F	189.96 F	234.79 D	224.49	0.0660
6855		208.59 D	230.29 E	213.01 H	288.31 F	235.05	0.3663
6856					263.58 E	263.58	-0.0846
6857	215.93 E		232.74 E	210.03 G	322.99 H	245.42	0.3408
6858	206.24 D	177.33 A	189.59 B	143.72 B	242.94 D	191.96	-0.7004
6859				161.39 C	229.54 D	195.46	-0.5753
6860					256.83 E	256.83	-0.1697
6861					314.55 H	314.55	0.5585
6862				127.69 A	214.64 C	171.16	-1.0860
6863	170.24 C			172.13 D	262.67 E	201.68	-0.4713
6864	208.42 E			206.46 G	285.00 F	233.29	0.1315
6901	199.49 D	190.65 C	216.29 D	184.75 E	322.46 H	222.73	-0.0639
6902	201.58 D	207.57 D	219.99 E	216.28 H	269.27 E	222.94	0.1152
6903	217.19 E	208.58 D	226.71 E		270.83 E	230.83	0.0965
6904		197.98 C	209.86 D		253.97 E	220.60	-0.2023
6905	241.81 G	217.96 E	257.78 G			239.18	0.6929
6906	235.75 G	203.58 D	224.81 E	220.11 H	251.36 E	227.12	0.2081
6907	237.81 G	183.37 B	228.55 E	197.17 F	228.31 D	215.04	-0.0876
6908	200.47 D	186.52 B	201.44 C	191.47 F	252.77 E	206.53	-0.3210
6909	204.03 D	189.18 C	219.89 E	179.98 E	316.10 H	221.84	-0.0775
6910	263.42 I	201.01 D	227.61 E	202.03 G	269.06 E	232.63	0.2584
6911	278.82 I	221.83 F	221.10 E	187.22 E	310.72 H	243.94	0.4648
6912	238.57 G	176.08 A	225.36 E	165.93 C	310.19 H	223.23	-0.1067
6913	232.93 F	175.25 A	249.50 F	177.40 D	313.49 H	229.71	0.0730
6914	250.64 H	196.55 C	209.34 D	170.03 D	279.45 F	221.20	-0.0595
6915	270.50 I	195.62 C	240.64 F	165.76 C		218.13	0.1780
6916	231.03 F	209.17 D	237.60 F			225.93	0.3217
6917	248.34 H	202.65 D	220.81 E	202.68 G	291.06 F	233.11	0.2364
6918	245.10 G	233.97 G	225.74 E	216.53 H	259.73 E	236.21	0.4806
6919	231.97 F	193.05 C	239.08 F	195.70 F	384.33 G	248.83	0.4130
6920	270.74 I	211.88 E	203.54 C	211.56 H	264.83 E	232.51	0.2627
6921	220.10 F	184.71 B	203.94 C	192.51 F		200.32	-0.2514
6922	231.49 F	211.48 E	228.80 E	167.06 C	227.29 D	213.22	-0.0470
6923	230.46 F	231.79 G	237.16 F	198.62 F	314.16 H	242.44	0.5275
6924	241.29 G	204.84 D	227.03 E	215.70 H	301.57 H	238.09	0.3552
6925	259.04 H	201.33 D	222.23 E	216.00 H	297.81 H	239.28	0.3555
6926	240.67 G	187.16 C				213.91	-0.0540
6927	231.69 F	195.93 C	232.10 E	200.53 G		215.06	0.1614
6928	223.38 F	196.54 C	231.70 E	184.50 E		209.03	0.0283

Appendix IV (cont'd)

Prov.	Site 1	2	3	4	5	Means Raw	Means Standardized
6929	226.50 F	175.64 A		190.74 F		197.63	-0.2356
6930	206.83 D	183.65 B	273.34 H	190.90 F	258.33 E	222.61	0.1108
6931	204.21 D	200.35 D	218.80 E	211.41 H	329.40 H	232.83	0.1905
6932	251.03 H	184.10 B	222.02 E	208.05 G	285.61 F	230.16	0.1251
6933	252.83 H	193.11 C	245.85 F	211.34 H	282.94 F	237.21	0.3485
6934	209.86 E	212.75 E	194.56 B	186.01 E		200.80	-0.1398
6935		188.63 C	209.76 D	204.66 G		201.02	-0.1082
6936	198.68 D	177.13 A	185.48 B	147.10 B	224.83 D	186.64	-0.7818
6937	210.93 E	179.49 A	156.50 A			182.31	-0.9615
6941	219.98 F	207.73 D	244.34 F	184.72 E	289.83 F	229.32	-0.2196
6942	193.70 D	205.96 D	197.66 C	180.71 E	284.21 F	212.45	0.1936
6943	232.61 F	202.94 D	213.08 D	185.48 E	337.96 H	234.41	0.1708
6944	238.33 G	179.67 A	218.37 E	152.54 B		197.23	-0.3601
6945	209.88 E	185.06 B	215.99 D			203.64	-0.3184
6946	230.42 F	193.96 C	187.38 B	155.70 C		191.87	-0.4664
6947	216.11 E	204.50 D	232.58 E	187.58 E	276.61 F	223.48	0.0935
6948	226.47 F	184.21 B	245.55 F	194.07 F	279.14 F	225.89	0.0907
6949	234.88 G	184.37 B	217.69 E	174.57 D		202.88	-0.1997
6950	211.34 E			180.94 E		196.14	-0.1852
6952	238.28 G	190.57 C	235.06 E	209.68 G		218.40	0.2181
6953	228.36 F	216.38 E	242.76 F	196.65 F	282.48 F	233.33	0.3462
6954	267.49 I	217.28 E	215.50 D	204.93 G	297.75 H	240.59	0.4123
6956	226.60 F	207.53 D	247.99 F	167.78 C		212.48	0.1623
6957	235.17 G	194.91 C	250.80 F	207.43 G		222.08	0.3464
6961	217.74 E		213.37 D	166.57 C	203.27 C	200.24	-0.4389
6969	208.53 E			141.78 B	220.78 D	190.36	-0.6712
6975	204.90 D	201.82 D		186.32 E		197.68	-0.0690
6979	154.17 B				180.31 B	167.24	-1.1837
7000	115.96 A				127.86 A	121.91	-1.8536

Appendix V. Fifteen year (1984) survival (%) and Scott-Knott clusters for all five test sites

Prov.	Site 1	2	3	4	5	Means Raw	Means Standardized
6804	93.7 H			87.5 H	79.2 F	86.80	0.0057
6807	33.3 B			62.5 E	77.1 F	57.63	-0.0022
6808				89.6 H	91.7 G	90.65	0.0053
6811				54.2 D	87.5 G	70.85	-0.0006
6850				85.4 H	93.7 G	89.55	0.0051
6851	89.6 G	52.0 E	61.3 F	83.3 G	52.1 D	67.66	0.0022
6852	52.1 E	56.0 E	54.7 E	91.7 J	95.8 G	70.06	0.0028
6853				85.4 H	93.7 G	89.55	0.0058
6854	77.1 E		54.7 E	64.6 F	100.0 G	74.10	0.0029
6855		72.0 G	45.3 C	83.3 H	47.9 C	62.13	0.0026
6856					83.3 F	83.30	0.0016
6857	79.2 E		76.0 G	72.9 F	66.7 E	73.70	0.0034
6858	77.1 E	49.3 D	44.0 C	47.9 D	97.9 G	63.24	0.0002
6859				83.3 G	91.7 G	87.50	0.0040
6860					72.9 F	72.90	-0.0002
6861					91.7 G	91.70	0.0023
6862				77.1 G	93.7 G	85.40	0.0035
6863	54.2 B			70.8 F	91.7 G	72.23	0.0013
6864	62.5 C			81.2 H	93.7 G	79.13	0.0032
6901	62.5 C	54.7 E	44.0 C	64.6 E	89.6 G	63.08	0.0003
6902	87.5 G	50.7 D	49.3 D	62.5 E	100.0 G	70.00	0.0022
6903	77.1 E	58.7 F	45.3 C		95.8 G	69.23	0.0021
6904		37.3 B	48.0 D		97.9 G	61.07	-0.0002
6905	58.3 B	44.0 C	45.3 C			49.20	-0.0017
6906	85.4 G	49.3 D	45.3 C	70.8 F	54.2 D	61.00	0.0004
6907	54.2 F	53.3 E	45.3 C	50.0 D	39.6 C	48.48	-0.0025
6908	62.5 H	61.3 G	57.3 E	95.7 J	95.8 G	74.52	0.0052
6909	75.0 E	54.7 E	53.3 E	66.7 E	77.1 F	65.36	0.0014
6910	85.4 G	54.7 E	52.0 E	70.8 F	43.7 C	61.32	0.0012
6911	52.1 G	26.7 A	58.7 F	39.6 C	16.7 A	38.76	-0.0058
6912	85.4 G	61.3 F	46.7 D	62.5 E	85.4 F	68.26	0.0017
6913	50.0 E	44.0 C	62.7 F	50.0 D	45.8 C	50.50	-0.0022
6914	54.2 F	40.0 C	61.3 F	77.1 G	47.9 D	56.10	-0.0006
6915	50.0 E	52.0 D	41.3 C	58.3 E		50.40	-0.0017
6916	52.1 G	57.3 E	30.7 A			46.70	-0.0019
6917	70.8 D	54.7 E	49.3 D	62.5 E	79.2 F	63.30	0.0006
6918	87.5 H	53.3 E	58.7 F	47.9 D	87.5 G	66.98	0.0016
6919	64.6 D	58.7 F	58.7 F	68.7 F	31.2 B	56.38	0.0001
6920	47.9 E	45.3 C	49.3 D	58.3 E	89.6 G	58.08	-0.0010
6921	79.2 E	50.7 D	24.0 A	54.2 E		52.03	-0.0019
6922	70.8 D	65.3 F	49.3 D	50.0 D	31.2 B	53.32	-0.0006
6923	68.7 D	49.3 D	69.3 H	81.2 G	60.4 E	65.78	0.0019
6924	83.3 F	34.7 B	56.0 E	45.8 D	89.6 G	61.88	-0.0005
6925	37.5 C	42.7 C	57.3 F	62.5 E	39.6 C	47.92	-0.0024
6926	62.5 C	50.7 D				56.60	0.0005
6927	60.4 C	50.7 D	54.7 E	37.5 C		50.83	-0.0017
6928	79.2 G	38.7 C	48.0 D	72.9 F		59.70	0.0004

Appendix V (cont'd)

Prov.	Site 1	2	3	4	5	Means Raw	Means Standardized
6929	72.9 D	69.3 G		64.6 E		68.93	0.0033
6930	47.9 A	25.3 A	72.0 H	91.7 J	58.3 D	59.04	0.0002
6931	29.2 G	56.0 E	50.7 D	60.4 E	43.7 C	48.00	-0.0024
6932	54.2 E	54.7 E	60.0 F	77.1 G	58.3 D	60.86	0.0006
6933	43.7 A	46.7 C	36.0 B	75.0 F	87.5 G	57.78	-0.0010
6934	68.7 D	44.0 C	38.7 B	37.5 C		47.22	-0.0030
6935		61.3 F	56.0 E	33.3 C		50.20	-0.0006
6936	89.6 G	62.7 F	54.7 E	68.7 F	72.9 F	69.72	0.0026
6937	79.2 E	46.7 C	45.3 C			57.07	0.0002
6941	77.1 F	40.0 C	58.7 F	35.4 C	62.5 E	54.74	-0.0015
6942	70.8 D	56.0 E	41.3 C	52.1 D	64.6 E	56.96	-0.0006
6943	64.6 C	37.3 B	52.0 D	68.7 F	56.2 D	55.76	-0.0014
6944	37.5 A	33.3 B	49.3 D	25.0 B		36.28	-0.0059
6945	47.9 A	36.0 B	60.0 F			47.97	-0.0019
6946	35.4 A	34.7 B	28.0 A	41.7 C		34.95	-0.0064
6947	27.1 A	41.3 C	52.0 D	54.2 D	54.2 D	45.76	-0.0034
6948	45.8 C	36.0 B	41.3 C	60.4 E	54.2 D	47.54	-0.0034
6949	37.5 C	45.3 C	58.7 F	56.2 D		49.42	-0.0019
6950	56.2 B			54.2 D		55.20	-0.0019
6952	66.7 D	42.7 C	62.7 F	68.7 F		60.20	0.0009
6953	72.9 D	49.3 D	53.3 E	70.8 F	77.1 F	64.68	0.0011
6954	70.8 D	61.3 F	72.0 H	81.2 G	70.8 F	71.22	0.0036
6956	56.2 B	40.0 C	58.7 F	12.5 A		41.85	-0.0044
6957	66.7 D	48.0 C	58.7 F	29.2 B		50.65	-0.0016
6961	68.7 D		50.7 E	72.9 F	58.3 E	62.65	0.0006
6969	56.2 G			89.6 H	95.8 G	80.53	0.0038
6975	50.0 B	48.0 D		35.4 C		44.47	-0.0033
6979	60.4 C				95.8 G	78.10	0.0018
7000	50.0 F				35.4 C	42.70	-0.0040